WATER ECOLOGY SECTOR REPORT

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INTRODUCTION

The Water Ecology breakout group included participants from academia, federal environmental agencies, the National Wildlife Federation and the Mille Locs Band of Ojibwe Tribe.

The discussion group was asked to interpret the four questions broadly to reduce the chance that significant issues would be overlooked. Because this was an initial effort, failing to include potentially critical issues was considered a greater mistake than including issues that, upon further study, turn out to be relatively unimportant. The participants were not asked to make quantitative assessments of the impacts that they discussed.

THE 4 QUESTIONS ADDRESSED

1. What are the current concerns?

• ***Land-use.*** The most important source of impacts on aquatic systems in the Upper Great Lakes region was thought to be land-use – specifically agriculture and urbanization (including industrial uses). These types of land-use changes can lead to direct loss or degradation of aquatic systems (e.g. filling of wetlands for agriculture and siltation of streams due to runoff from agriculture).

• ***Agriculture.*** Fertilizer and pesticide runoff produce widespread and detrimental impacts on aquatic ecosystems. In addition to these well known concerns, questions were raised about industrial farms and how they handle animal wastes. On one hand, manure was described as having a potentially large impact on phosphorus and ammonia levels in aquatic systems. On the other hand, European studies show that manure can be an important source of nutrients when spread across the landscape.

• ***Urbanization.*** A study linking increasing urbanization with decreasing scores on a biotic index was discussed. The aspect of climate change that may prove to be most important in terms of aquatic ecosystem health is how land-use patterns (e.g. urbanization or sprawl) change as a result of climate change and climate change mitigation policies.

• ***"Leap-frogging."*** Aquatic systems are particularly vulnerable to "leap-frogging" (i.e., building vacation homes in remote areas causes degradation "leaps" from cities to more rural areas), especially groundwater systems (resulting from more well drilling and waste disposal in previously unimpacted areas).

• ***Population growth.*** Land-use issues are closely tied to population growth, which was identified as an important stressor.

• ***Pollution.*** Important concerns included mercury deposition (leading to reproductive and potentially fatal, developmental impairments in aquatic life); eutrophication (leading to reduced dissolved oxygen and potential species loss) and acid rain (impairing and potentially killing fish and plant life). Other sources of point and non-point source pollution and existing contaminant loads in aquatic sediments and biota were also important concerns.

• ***Additional stresses.*** The alteration of lake levels in the Great Lakes, the shoreline modification (related to human settlement along shores), the loss of Great Lakes coastal wetlands (related to the alteration of lake levels and shoreline modification), and the invasion of exotic species were all discussed as areas of importance. The current concerns are summarized in Figure 1.

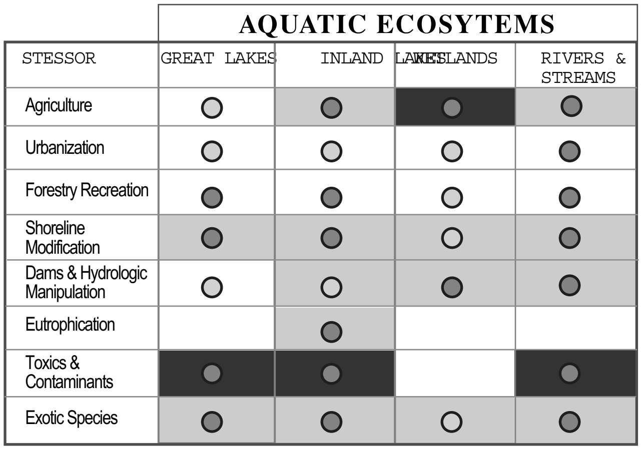

Figure 1: Major stressors on aquatic ecosystems in the Upper Great Lakes region.

Strongly impact ecosystem

Very strongly impact ecosystem

Likely to interact with or be further impacted as a result of climate change

Likely to strongly interact with and be impacted by climate change

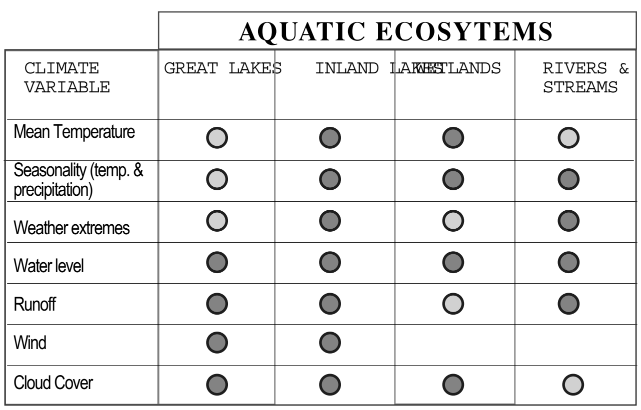

Figure 2. Climate factors that affect the structure and function of aquatic ecosystems in the Upper Great Lakes region. All of these climate factors are likely to be affected by global climate change.

Important impacts

Very important impacts

2. How may climate change impact our lives?

It was recognized that any changes in climate could have strong and hard-to-predict impacts on aquatic systems. Examples that were discussed included:

- ***Water temperature increase.*** Potential effects of a temperature increase on deep inland lakes could lengthen the period of thermal stratification and decrease the volume of the layer of water beneath the thermocline. This could lead to a decrease in dissolved oxygen, decrease in primary productivity, and a decrease in cold water fish populations.

- ***Decrease in ice cover.*** A decrease in ice cover could reduce winter kills (i.e. fish that die because of insufficient dissolved oxygen in the water under the ice). An overall change in the seasonal patterns of freezing and thawing could interfere with aspects of fish (and other species) life histories, such as the timing of reproduction.

- ***Decrease net water basin supply.*** Decreased rates of supply, coupled with increased rates of evaporation, could lead to decreased lake levels and the widespread loss of wetlands.

A summary of the discussed impacts on various water bodies from changes in climate factors is presented in Figure 2. Interactions among the climate factors shown in the table were thought to be highly likely but beyond the scope of the discussion.

3. What additional information do we need?

The discussion in this section fell into three categories: better understanding, better model development and implementation, and better general information and better data.

Better understanding

Improved regional climate models are needed that incorporate feedbacks between climate and ecological aspects of the Great Lakes. The group discussed several issues related to modeling.

- ***Recharge mechanisms.*** A main informational need with respect to groundwater models is an understanding of recharge mechanisms on the larger scale. The focus of most groundwater models is shallow system aquifers. Some work has been done to estimate flow to and from the lakes and the flow of groundwater. Groundwater exchanges with the lakes are highly variable by area because of soil type and underlying geology.

- ***Runoff.*** Another informational need is a better understanding of runoff. Better parameterization of runoff in GCMs and RCMs is important because incorrect treatment of runoff can cause errors in surface fluxes. To develop improved parameterizations, there is some question as to whether runoff data and recharge data are both needed, because the processes tend to cancel to a large degree. The degree of cancellation depends on the scale of the model being used and the spatial patterns of the aquatic systems in the model. Currently there are no projects at the U.S. Geological Survey (USGS) to link runoff to these models.

Better model implementation

- ***Linkage.*** Models for groundwater, river flow, runoff, and wetlands need to be linked together. This linkage will require the development of models for wetlands (currently there are no generic wetland ecosystem model of which the group was aware). It appears that there are currently models under development that are likely to be useful – it was mentioned that NCAR has a version of VEMAP (Vegetation/ Ecosystem Modeling and Analysis Project) that models the effects of current and doubled CO_2 at 50 km resolution that includes the Great Lakes. The USGS also has models of groundwater flow that are at a small scale (RASAS studies – watershed scale) that could potentially be linked to produce a regional model.

- ***Calibration.*** Existing groundwater models need to be calibrated using data from periods of major hydrologic stress. Currently there is not sufficient information available.

- ***Integrated databases.*** There is potential to link three existing groundwater models for different parts of the region and then tie in runoff. It may be useful to get NOAA and the Army Corps of Engineers involved. It was also suggested that there is a lot of information available on lake levels and stream flow that could be linked with existing forest, agriculture, wetland distribution, and groundwater databases. A major effort should be put into integration of the existing databases and models to improve understanding. The focus of these integrated groundwater models should be on hydrologic balance at a landscape scale. Future links envisioned by the group would be to tie in urbanization and other types of land-use change. The group agreed that land-use changes are going to be a key factors determining the fate of aquatic systems. Finally, the integrated groundwater and runoff models should be linked to GCMs and RCMs.

- ***Spatial Scale***. Broad-based models for the Great Lakes or wetlands are not likely to be useful because effects related to climate change are likely to be very site-specific. It is possible to get (opposite) effects due to some climatic change in adjacent sites – the results have to do with the water budget for each water body. Local flow paths dominate small-scale effects. As a result, predictions need to be presented carefully and with respect to specific sites; general broad scale predictions will be incorrect and inappropriate.

• ***Temporal scale.*** Another problem with current models is the assumption that the Great Lakes area has remained unchanged over time. Data from several centuries needs to be examined in order to better understand the effects of changing climate. We are currently in a period of declining lake levels. Lake levels also show strong periodicities at various time scales that are likely to be climate-driven. Both of these would not be clear without the long-term data sets that are available. There are likely to be strong parallels between the inland lakes and the Great Lakes that may be identifiable through paleoecological studies.

Better general information and better data

• ***How climate shapes ecosystems.*** Research should address the question of "How does climate shape aquatic ecosystems?" Climate change is likely to lead to a wide variety of ecosystem feedbacks. As described above, effects are likely to differ – even in systems that appear similar – due to differences in water regime, soil/parent material, and location on the landscape.

• ***Exotic species.*** The habitat needs and ecological requirements for a whole collection of species remain unknown and must be studied. This is especially true for those that are likely to invade and possibly dominate aquatic systems. The forces and factors that are currently restricting ranges (including climate factors) must be understood to make better predictions about what will happen in the future. The population ecology of many species could be dramatically altered by changes in climate.

• ***Air quality.*** Information is needed to link nitrogen deposition patterns and the impacts on levels in ecosystems. The Great Lakes are probably not nitrogen limited, although this may vary seasonally. In wetlands, nitrogen can be a key limiting nutrient. Peatlands may be particularly at risk because *Sphagnum* species are killed by high nitrogen levels. Mercury deposition is also important to examine.

• ***New data.*** Information gathering should focus on key stressors identified in Figure 1, especially those that are susceptible to climate change impacts. One important data need relates to the natural fluctuations in groundwater level – most data currently reflects water levels in pumped systems (i.e. systems in which the water level is at least in part determined by human activity). Good data on sunlight, especially in remote areas like the centers of each of the Great Lakes is also needed. These data would help in the estimation of primary productivity in aquatic systems.

• ***Long-term lake levels.*** The relationships between long-term lake level data and other long term climate data (i.e., CO_2 from ice cores) should be investigated.

Organizing research and impact assessments

From the previous list it is clear that additional research is needed. The following specific tasks and general guidelines resulted from a discussion of the need for further research.

Specific tasks

1. Develop better proxies for assessing the effects of climate change in the past (in addition to the records that already exist from long term Great Lakes water level studies).

2. Develop an understanding of the connection between aquatic ecosystems, the watershed, and local and regional hydrology.

3. Develop basic ecosystem models for wetlands.

4. Develop and integrate regional models of climate, landscapes, hydrology, and terrestrial and aquatic ecosystems.

5. Improve the understanding of climate as a basic structuring principle of aquatic ecosystems.

6. Obtain more information about the key stressors identified in Figure 1.

General guidelines

1. Develop location-specific studies. An overall feeling was that the heterogeneity and interconnectedness of aquatic systems makes any sort of generalization about stressors or effects of climate change very difficult.

2. In terms of discussing impacts, it may be useful to divide aquatic systems into those *directly and indirectly* influenced by the Great Lakes.

3. Streams, groundwater-fed systems and storm-responsive systems should be examined separately. Alternatively, streams and rivers could be divided into those that are *high and low* in the landscape.

4. Wetlands should be assessed on a gradient from lake-influenced to non-lake influenced.

4. How do we cope with climate change?

This session was short and focused on the development of the summary list below.

1. ***Data usage***. Maximize and integrate current data sets and models. This will increase the usefulness of currently available information and predictive ability.

2. ***Economics assessment.*** Promote consideration of environmental costs (externalities) in cost/benefit assessments of various planning and mitigation strategies. Unless this is done, economic and policy decisions intended to increase the value of our world in future years will fail to promote healthy ecosystems.

3. ***Comprehensive studies.*** Incorporate climate change-related variables into ongoing studies of other stressors of aquatic systems. This is essential to determining the extent and type of aquatic system vulnerability.

4. ***Outreach.*** Increase efforts at public outreach and education about potential effects of climate change on aquatic ecosystems. Until the public is informed they will not support enlightened policies.

5. ***Land-use strategies.*** Promote land-use planning that will minimize potential impacts of extreme events. Land-use patterns can either increase or decrease the vulnerability of ecosystems.

6. ***Restoration.*** Encourage development of adequate restoration techniques for aquatic systems. It is not enough to decide to restore and promote healthy aquatic systems, one must know how to implement these goals.